Docket No.: M0025.0291/P291
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Anthony T. Walsh

Application No.: 10/603,784

Filed: June 26, 2003 — Art Unit: Not Yet Assigned

For: GEOGRID OR MESH STRUCTURE — Examiner: Not Yet Assigned

CLAIM FOR PRIORITY AND SUBMISSION OF DOCUMENTS

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Applicant hereby claims priority under 35 U.S.C. 119 based on the following prior foreign application filed in the following foreign country on the date indicated:

Country	Application No.	Date
United Kingdom	0214931.8	June 27, 2002

In support of this claim, a certified copy of the said original foreign application is filed herewith.

Dated: July 31, 2003

Respectfully submitted,

By [signature]

Stephen A. Soffen
Registration No.: 31,063
DICKSTEIN SHAPIRO MORIN & OSHINSKY LLP
2101 L Street NW
Washington, DC 20037-1526
(202) 785-9700
Attorney for Applicant

1646024 v1; Z@2W01!.DOC

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed Andrew Gersey

Dated 15 July 2003

Patents Form 1/77

Patents Act 1977
(Rule 16)

The
Patent Office

28JUN02 E729334-4 D03312
P01/7700 0.00-0214931.8

THE PATENT OFFICE
27 JUN 2002
RECEIVED BY HAND

27 JUN 2002

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

1. Your reference — GBP84927

2. Patent application number (The Patent Office will fill in this part) — 0214931.8

3 Full name, address and postcode of the or of each applicant (underline all surnames)

Tensar International Limited,
New Wellington Street
BlackburnBB2 4PJ
United Kingdom

Patents ADP number (if you know it) — 8413577001

If the applicant is a corporate body, give the country/state of its incorporation — U.K ao A/L 12.7.02 JD.

4. Title of the invention — Geogrid

5. Name of your agent (if you have one)
"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

Marks & Clerk
57 - 60 Lincolns Inn Fields
London WC2A 3LS

Patents ADP number (if you know it) — 18001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number

Country	Priority application No (if you know it)	Date of filing (day / month / year)

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing (day / month / year)

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d)) — Yes

Geogrid

Background of the Invention

The present invention relates in general to geogrids. A geogrid is a grid whose primary purpose is to strengthen or reinforce soil and has open meshes into which soil particles can lock. If made by orienting a plastics starting material, the starting material would normally have a thickness greater than about 1, 1.5 or 2 mm. A geogrid is in effect made up of strands which are interconnected at bars running across the geogrid in the TD or are interconnected at junctions or intersections, whether or not the strands are continuous throughout the geogrid as they would be in the case of say a woven geogrid. The thickness of a geogrid, as measured at the junction, would be greater than about 0.5 mm or 0.75 mm and may well be greater than about 1.00 mm or 1.5 mm or 2.0 mm.

Geogrids can be manufactured in many different ways, for instance by stitch bonding fabrics made of for instance polyester filaments and applying a flexible coating such as a PVC coating, or by weaving or by knitting, or even by spot-welding oriented plastic strands together. However, although not confined to such materials, the present invention is primarily concerned with geogrids which are formed by uniaxially or biaxially orienting a plastics sheet starting material which has been provided with holes. The holes form meshes in the product. In a uniaxially oriented geogrid of this type, TD bars are interconnected by strands. Biaxially oriented geogrids of this type comprise oriented strands and junctions at which the strands meet, substantially each strand having each end connected to such a junction, whereby sets of parallel tensile members run through the geogrid, each tensile member being formed of a succession of substantially aligned strands and respective said junctions interconnecting the strands.

The present invention also relates to methods of making geogrids. In methods using a plastics sheet starting material which has been provided with holes, a stretch is applied to stretch out zones between adjacent holes and form oriented strands from such

zones, thereby providing a uniaxially oriented geogrid. A stretch can be applied in a direction at right angles to the first stretch to stretch out zones between other adjacent holes and form oriented strands from the latter zones, whereby portions between groups of holes form junctions interconnecting the oriented strands and a biaxially-oriented geogrid is formed.

US 4 374 798 and US 5 053 264 disclose uniaxially and biaxially stretched and oriented mesh structures of the general type with which the present invention is concerned, but those mesh structures do not have great stability in the diagonal direction in that the mesh structures can be extended in the diagonal direction without great application of force due to parallelogram distortion of the mesh structure. Uniaxially geogrids are extensively used where the stress is primarily in one direction, for instance when reinforcing embankments. In such structures, stresses are transferred from the soil along the strands and into transverse bars which can be thicker than the strands and are anchored in the soil. Relative movement between the soil and the geogrid is prevented close to the transverse bars but can take place along the length of the machine direction strand. Biaxial geogrids are extensively used in the reinforcement of granular layers in roads, parking areas, container storage areas and other hard standings. While the previous geogrids have high strength and stiffness in the longitudinal and transverse directions, the loading from for example a heavy wheeled vehicle imposes radial stresses in the geogrid, which cannot be supported by the geogrid and cause great distortion of the geogrid.

It is desirable to provide more strength in directions other than the machine direction and transverse direction without grossly reducing the strength of the mesh structure in at least one of the machine and transverse directions.

It is an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

Any discussion of the prior art throughout the specification is not an admission that such prior art is widely known or forms part of common general knowledge in the field.

The Invention

The invention provides geogrids as set forth in Claim 1, 8, 19, 50, 51 or 52 and methods as set forth in Claims 27, 31, 41, 44, 53 or 54. The invention also extends to a method of strengthening a particulate material, comprising embedding in the particulate material a geogrid of the invention, and further extends to a geotechnical construction comprising a mass of particulate material strengthened by embedding therein a geogrid of the invention.

The geogrid of Claims 1 and 19 provides angled orientation of the pairs of strands between the transverse bars and reduces any tendency for relative movement between the strands and the soil, creating a stiffer and more effective reinforcement anchor.

In the geogrid of Claim 8, the triangular meshes of the geogrid provide a robust structure having high tensile strengths along said tensile members. One series of tensile members can extend in the machine direction or in the transverse direction, and it is found that in the direction at right angles, the geogrid has good strength because extension would require buckling of oriented strands running at right angles to the force applied and such buckling is impeded by soil in which the geogrid is buried. The triangular or regular hexagon form produces a structure with isotropic stiffness in the plane of the geogrid, which enables the geogrid to distribute load more uniformally in geotechnical applications; if the strength of the geogrid is measured around 360°, there will be at least six peaks but the dips are less great than with rectangular structures. Thus the geogrid is more able to carry radial stresses, with less deformation, leading to a stiffer and more effective enforcement anchor in soil reinforcing applications and also leading to more effective load distribution when used to support e.g. wheeled vehicle loading or point loading such as imposed by heavy construction equipment. Oriented polymers are particularly well suited for geotechnical applications as the typical stresses are highly directional along the tensile members, the high directionality of oriented polymer materials enabling the material's stiffness and strength to be directed along the length. Using the invention, there is very little waste material and roughly 50% by weight of the material is in the strands, the remainder being in the junctions.

The method of Claim 41 provides a technique for relatively inexpensively forming a more complex pattern of holes, for instance from a starting material that has been punched with a simple “square” pattern, and the final pattern can for instance be as in GB 2 034 240 A, GB 2 096 531 A or GB 2 108 896 A, or as in Claim 44 below.

The tensile members which are formed provide the strength of the geogrid, and are not just thin, highly oriented filaments formed by the rupture of a membrane.

Definitions

The term "oriented" means molecularly-oriented. In general, when an oriented strand is referred to, the preferred direction of orientation is longitudinal of the strand.

"Uniaxial" and "biaxial" mean uniaxially-oriented and biaxially-oriented, respectively.

In relation to a mesh structure, "biaxially-oriented" means that the mesh structure has been stretched in two directions generally at right angles to each other.

The holes in the starting material may be through-holes or blind holes. If the holes are blind, the film or membrane in the hole will either rupture on stretching, or may remain as a thin membrane. The holes can be formed by punching them out from the starting material, as disclosed in US 4 374 798, or can be formed by extrusion as disclosed in US 5 053 264, or can be formed by suitable embossing, or in any other appropriate manner.

"Strictly uniplanar" means that the material or structure is symmetrical about a median plane parallel to its faces. In general, a uniplanar starting material will give a uniplanar structure when stretched.

"Substantially uniplanar" means that the material or structure does not deviate so much from strict uniplanarity that orientation is not comparable on each face of the biax product.

"Substantially rectilinear" means that some deviation from rectilinearity is permitted provided the tensile members without too much movement longitudinal of the tensile member as they align. In general, it is preferred that there should not be more than about 5% or 3% extension before taking up the force.

The "starting material" is the material immediately before initiation of the first stretch.

The stretch ratios are as measured after releasing the stretching force or after annealing if annealing is carried out, and as measured on the surface of the structure.

"Truth lines" are parallel lines applied (normally by printing or drawing) to the starting material, normally but not necessarily in two directions parallel to the MD and TD respectively. Truth lines are only used for experimental work and are not normally used in production runs.

"MD" is the machine direction, normally the long dimension of the geogrid.

"TD" is the transverse direction, substantially at right angles to the MD.

The "hexagons" are notional shapes defined by the centres of the holes. The hexagons referred to preferably do not have any holes within the hexagon, other than parts of the holes delineating the shape of the hexagon.

"Grooving" as used herein is forming depressions in a zone of a plastics material without material removal when the plastics material is at a temperature below the lower limit of its melting range, prior to stretching the respective strand-forming zones. There is a description of grooving in GB 2 128 132 A.

The term "particulate material" includes rocks, stones, gravel, sand, earth, clay, aggregate held by a binder such as asphalt or cement, concrete, or any other particulate or cohesive material used in geotechnical engineering or building. The term "soil" as used herein has the same meaning as "particulate material".

Preferred Features

The dependent claims set forth preferred and/or optional features of the invention.

In a general sense, if each hexagon in the starting material is positioned so that two opposite holes delineating the hexagon are substantially aligned in the MD, the geogrid will have TD strands but no MD strands - there will be two sets of strands (i.e. of the tensile members) at say roughly 30° to the MD, forming triangular meshes with a said junction at each corner.

When using the method of Claim 31, it was found on stretching that there was a tendency for oriented strands entering opposite sides of a junction to be slightly offset, i.e. not to be perfectly aligned. This gave a slight strength reduction and also made the geogrid appear less satisfactory - although the appearance of the geogrid may not matter in practice, it affects the attitude of buyers. It has been found that this offset can be reduced or eliminated if in the starting material the angles of any hexagon are not equal though the sides of the hexagon can be substantially equal. In one arrangement, the hexagons are slightly foreshortened in the MD so that the dimension of the hexagon, as measured from the centre of one hole to the centre of the opposite hole in the MD, is less than the corresponding dimensions between respective opposite pairs of the other holes. The minimum ratio of the first-mentioned dimension to the other dimensions is preferably about 0.75:1 or 0.8:1 and the maximum ratio is preferably about 0.95:1 or about 0.9:1, a suitable ratio being about 0.85:1. Put the other way and giving slightly different values, the minimum ratio may be about 1:1.1 or 1:1.14 and the maximum ratio may be about 1:1.3 or 1:1.23, a preferred value being about 1:1.17.

When using the method of Claim 44, it is preferred that the weakened zones have a percentage reduction at their centre points which is at least about twice, three times or four times that of the non-weakened zones.

When made by orienting a plastics sheet starting material, any suitable plastics material can be used, such as polypropylene or high density polyethylene. Preferably,

the starting material is strictly uniplanar, which can be achieved by extruding the starting material and punching. However, satisfactory results can be obtained with any substantially uniplanar starting material.

For biaxial geogrids, normal practice is to carry out the first stretch in the MD, and this is found to give a more even and controllable product - the MD stretch can be carried out using stretching rolls and the second, TD stretch using a stenter. However, it is possible to carry out the first stretch in the TD but the product is less even because *some MD strands start to stretch and all strand-forming zones are affected during the* first stretch. If a suitable stenter could be designed, it would be possible to carry out both stretches simultaneously, though the produce may be inferior.

In practice, it is impossible to have precise control on the uniformity of the final structure. However, for the biaxial geogrids, it is desirable, not only for aesthetic reasons but also for improved multi-directional strength, to produce a structure in which the triangles of the meshes are substantially equilateral, i.e. the angles between the tensile members of the three series are substantially 60°. However, angles other than 60° can be chosen for certain applications, e.g. when providing unidirectional stress. *Such non-uniform structures could be provided by non-isotropic punching* or by a reduced TD stretch, or even by applying a larger TD stretch to give more TD cover.

The holes can be any suitable shape, such as circular, square, rectangular or hexagonal, and suitable shapes are specifically disclosed in Figure 31 of GB 2 256 164 A. Where there are blind holes as in Claim 41 or weakened zones as in Claim 44, the holes or zones can likewise be of any suitable shape, including the elongate shape of the grooves in GB 2 128 132 A. The ratio of the distance apart of the centres of adjacent holes to the width of the holes as measured along the line connecting the centres in preferably not less than about 1.5:1 and not greater than about 3:1.

The structures need not be uniform throughout, and the special arrangements shown in for instance GB 2 108 896 A or GB 2 034 240 A can be employed, or for instance, junctions can be consolidated as shown in Figures 7b and 7d of GB 2 295 353 A. However, the structure will normally extend substantially from edge

to edge and end to end of the geogrid, and there will be a multiplicity of said tensile members in each said set.

It is possible to place small holes in the centres of the hexagons so that small holes will be present in the centres of the junctions of the biaxial geogrids.

Preferred Embodiments

The invention will be further described by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a plan view of a portion of a first starting material;

Figure 2 is a plan view of the uniaxial geogrid made from the starting material of Figure 1;

Figure 3 corresponds to Figure 2, but shows an example of the thicknesses of the uniaxial product;

Figure 4 is a plan view of the biaxial geogrid made from the starting material of Figure 1;

Figure 5 is the same as Figure 4, but shows an example of the thicknesses of the geogrid;

Figure 6 shows the dimensions of the starting material in one specific example;

Figures 7a, 7b and 7c are schematic plan views of the biaxial product of the example, showing three tensile members that were subjected to tensile tests;

Figure 8a and 8b are schematic plan views of the biaxial product of the example, showing configurations that were subjected to tensile tests;

Figure 9 is a plan view of a portion of a second starting material;

Figure 10 is a plan view of the uniaxial geogrid made from the starting material of Figure 9;

Figure 11 is a plan view of the biaxial geogrid made from the starting material of Figure 9; and

Figure 12 is the same as Figure 11, but shows an example of the thicknesses of the geogrid.

Figures 1 to 5 - First Embodiment

The starting material 1 shown in Figure 1 is a strictly uniplanar sheet of extruded plastics material having planar parallel faces. Holes 2 have been punched in an array of hexagons 3 of substantially identical shape and size (only three of which are indicated) so that substantially each hole 2 is at a corner of each of three hexagons 3. For experimental purposes, truth lines 4 are shown printed on the central area of the portion of starting material 1 represented.

A first stretch is applied in the MD, i.e. in a direction substantially parallel to the MD sides of the hexagons 3. Due to the strength configuration of the starting material 1, the first stretch stretches out zones 5 between adjacent holes on the MD sides of the hexagons 3 to form oriented strands or ribs 6 from such zones 5 (see Figure 2 which shows the uniax material 7), the strands 6 interconnecting oriented TD bars 6'. A comparison of the truth lines 4' shown in Figure 2 with the truth lines 4 shown in Figure 1 shows that the junction centres in the uniaxial material 7 of Figure 2 have been slightly stretched out or oriented in the MD. As shown by the hatching lines in Figure 2 (shown only in the top part of the Figure), the ends of the strands 6 slope upwards into the junctions, forming re-entrants at around point 15 and leaving a thick zone 16 in the crotch between adjacent strands 6. The strands 6 interconnect TD bars 6', the strands 6 extending at a substantial angle to the MD and alternate strands 6 across the width of the uniaxial geogrid 7 being angled to the MD by equal and opposite angles, there being

no substantially MD strands. Between the locations 6" where the strands 6 meet the bar 6', the bar 6' is unoriented, and at the locations 6" the bar 6 is slightly oriented in the MD so that the orientation of the strands 6 extends across the bar 6' to the strands 6 on the other side of the bar 6'.

A TD stretch is then applied to the uniax material 7 to stretch out zones 8 on the remaining sides of the hexagons 3, between adjacent holes 2 which are on the sides of the hexagons 3 parallel to the MD. The zones 8 form oriented strands 9 (see Figure 4 which shows the biax product or geogrid 10). As can be seen from Figure 4, the centre portions of the original hexagons 3 form junctions or nodes 11 each interconnecting six oriented strands, 6, 9 in a structure in which substantially each strand 6, 9 (each strand 6, 9 except at the sides and ends of the geogrid) has each end connected to a junction 11 and groups of three strands 6, 9 form triangular meshes with a junction 11 at each corner. As considered in the TD, alternate angled strands 6 are angled to the TD by equal and opposite angles. In the geogrid, there are three sets or series of substantially parallel tensile members running through the structure 10, as indicated by the chain-dotted lines 12, 13, 14, respectively in the TD, at -30° to the MD and at +30° to the MD. Each tensile member 12, 13, 14 is formed of a succession of substantially aligned strands 6 or 9 and respective junctions 11 connecting the strands 6 or 9.

As shown by the hatching lines in Figure 4 (shown only in the top part of the Figure), each strand 6 or 9 forms a re-entrant 15 where it enters the junction 11 and the crotch 16 between adjacent strands 6 or 9 has been stretched out so that there is continuous orientation from the edge of one strand 6 or 9, around the crotch 16 and to the edge of the adjacent strand 6 or 9. The stretch ratio in the middle of the strands 6, 9 can be about 9:1, but in order to obtain as near as perfect 60° angles between the strands 6, 9, the TD strands 9 have to be stretched slightly more than the other strands 6. The reduction in thickness of the centres of the strands 6, 9 is about 75%, but with thicker starting sheets, more stretch can be applied to give the same percentage thickness reduction.

A comparison of the truth lines 4" of the biax product or geogrid 10 of Figure 4 with the truth lines 4' of the uniaxial geogrid 7 of Figure 2 shows that the centres of the junctions 11 have been very slightly stretched out or oriented in the TD and have been

very slightly thinned down. Thus the junction centres have slight biaxial orientation. In general, there is preferably some reduction of the centres of the junctions 11, say up to a maximum of about 20% reduction in thickness, but the stretching should not erode all the way through the junction 11. Overstretching in the MD causes the two MD strands 6 to act as one and pull a single strand out of the junction 11 so that the junction 11 is eroded and an offset structure is produced. Overstretching in the TD erodes the junction 11 and produces an irregular hexagon in the biaxial geogrid.

Example 1

Figure 6 is an enlarged view of part of the starting material 1 of Figure 1 and indicates the pitches (the distances between the centres) of the holes 2. The starting sheet 1 was nominally 4.7 mm thick polypropylene with 2% carbon black additive and the punch size was 5 mm diameter. It will be seen that the hexagons 3 are slightly foreshortened in the MD and in each hexagon 3, the ratio of the distance between the centres of the two opposite holes 2 on the MD axis of the hexagon 3 (18.5 mm) to the distance between the other remaining pairs of opposite holes 2 (21.7 mm) is 0.85:1 (or 1:1.17). The ratio of the distance apart of the centres of adjacent holes to the diameter of the holes is about 2.1:1.

The starting material 1 is given a first (MD) stretch to an overall stretch ratio of 3.79:1, and produces the uniax product 7 generally illustrated in Figure 2 and of which one part is specifically illustrated in Figure 3 with thicknesses at various points being indicated, in mm. The uniax product 7 of Figure 2 is then given a second (TD) stretch (with MD restraint) to an overall stretch ratio of 3.34:1, and produces the biax geogrid generally illustrated in Figure 4 and of which one part is specifically illustrated in Figure 5 with thicknesses at various points and two other dimensions being indicated, in mm. The junction centre-junction centre distance in Figure 5 is about 63.5 mm and the final overall stretch ratios are as in the individual MD and TD stretches (due to the MD restraint in the TD stretch). The junctions 11 have thinned down roughly 10% during the two stretches. 80% to 85% of the total stretch of the diagonal strands 6 was applied during the MD stretch, the remainder being applied during the TD stretch.

In each stretch, the stretching temperature was 120°C, and the stretching speed was up to 300 mm/min (in the laboratory - higher speeds would be used in production).

The final geogrid 10 was tested in two ways, firstly as a single tensile member test in the three directions illustrated in Figures 7a, 7b and 7c (TD tensile member 12, -30° tensile member 13 and +30° tensile member 14) and as a 6-mesh tensile test illustrated in Figures 8a (TD) and 8b (MD). Each test was continued until failure of the test piece.

For the single tensile member test, the tensile member was cut out of the geogrid 10 and was gripped on a junction 11 at either end. For the 6-mesh tensile test, the tests were as follows:

a - TD - grip on the extreme left-hand and right-hand junctions 11 (Figure 8a);

b - TD - grip on the left-hand three junctions 11 and on the right-hand three junctions 11 (Figure 8a);

c - MD - grip on the two junctions 11 at the top and the two junctions 11 at the bottom (Figure 8b).

In the 6-mesh test, once one strand failed, the other relevant strands immediately failed.

In each test, the strands 6, 9 broke where they entered the junctions 11.

The results were as follows:

	Single tensile member results			6-mesh results		
	TD	-30°	+30°	a	b	c
Max. load (kN)	1.156	1.000	1.070	1.182	3.428	2.381
Displacement at max. load (mm)	13.520	10.873	12.230	14.238	10.964	12.564

It would be seen that the "a" result for the 6-mesh gives a slightly higher maximum load than that on the single tensile member. It is believed that this is because on stretching, although the hexagon collapsed, some tensile stress was applied through the other strands once the centre strands had stretched out.

Figures 9 to 12 - Second Embodiment

The starting material 1 shown in Figure 9 is a strictly uniplanar sheet of extruded plastics material having planar parallel faces. Holes 22 have been punched on a rectangular grid whose axis extend in the MD and in the TD. By employing grooving, there are weakened zones 23 between alternate pairs of adjacent holes in each MD row, the weakened zones 23 being staggered as between adjacent MD rows so that a weakened zone 23 in one MD row is adjacent a non-weakened zone 24 in the adjacent MD rows on either side.

The grooving is applied using a tool having inclined faces and a radiused end, like a chisel point, and extends from one hole 22 to the adjacent hole, the grooving being applied while the starting material 21 is cold.

A first stretch is applied in the MD, and stretches out zones 25 between adjacent holes 22 in each TD row to form oriented strands 26 from such zones 25, the strands 26 interconnecting TD bars 27 (see Figure 12 which shows the uniax material 28). In the TD bars 27, between the locations 29 where the strands 26 meet the bar 27, the bar 27 is unoriented, and at the locations 29, the bar 27 is slightly oriented in the MD so that the

orientation of the strands 26 extends across the bar 27 to the strands 26 on the other side of the bar.

A TD stretch is then applied to the uniaxial material 28, to stretch out the weakened zones 23 to form oriented strands 30 without stretching out the non-weakened zones 24 to the same extent as the weakened zones 23 are stretched. In this way, the non-weakened zones 24 form junctions 31 each of which interconnects six of the oriented strands 26, 30 and forming a structure generally as in Figure 4, though the diagonal strands 26 are offset at the junctions 31 because the junctions 31 are extended in the TD. The axes of the angled strands 26 are at about 14° to the MD. Each junction 31 has two thicker zones interconnected by a thinner zone (see the example of Figure 12). At the centre points of the strands 30, the weakened zones 23 had a reduction in thickness of about 78% whilst at the centre points of the junctions 31, the non-weakened zones had a reduction in thickness of about 17%, the former reduction being about 4.6 or 4.65 times the latter. In practice, the tensile members formed by the diagonal strand 26, junction 31, diagonal strand 26, and so in sequence are effectively rectilinear because on applying tensile strength throughout the length, the "give" in the structure is negligible. There is some rotation of the junctions 31 but they are restrained by the remainder of the structure.

<u>Example 2</u>

The starting sheet thickness, material and punch size were as in Example 1. The MD pitch was 10.5 mm and the TD pitch 9.5 mm. The punch to form the grooves 23 had a 116° included angle with a radiussed tip, and was applied to each face of the material 21 to a depth of 16% of the sheet thickness, giving a total grooving of 32% of the sheet thickness. The MD and TD stretch ratios were respectively 4.00:1 and 2.21:1. Figure 12 indicates the thicknesses of various points on the product, in mm.

General

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise" and the like are used in an inclusive as opposed to an exclusive or exhaustive sense, that is to say, in the sense of "include, but not limited to".

The present invention has been described above purely by way of example, and modifications can be made within the spirit of the invention. The invention also consists in any individual features described or implicit herein or shown or implicit in the drawings or any combination of any such features or any generalisation of any such features or combination. Each feature disclosed in the specification, including the claims, abstract and drawings, may be replaced by alternative features serving the same, equivalent or similar purposes, unless expressly stated otherwise.

CLAIMS:

1. A geogrid comprising transverse direction bars interconnected by strands, at least some of the strands extending from one bar to the next at a substantial angle to the machine direction and alternate angled strands across the width of the geogrid being angled to the machine direction by equal and opposite angles.

2. The geogrid of Claim 1, wherein there are no substantially machine direction strands interconnecting the bars.

3. The geogrid of Claim 2, wherein the strands of each pair of adjacent angled strands meet immediately adjacent the respective bar.

4. The geogrid of any of the preceding Claims, wherein between the locations where the strands meet the bar, the bar is unoriented, and at the locations where the strands meet the bar, the bar is slightly oriented in the machine direction so that the orientation of the strands extends across the bar to the respective strands on the other side of the bar.

5. The geogrid of Claim 4, wherein between the locations where the strands meet the bar, the bars have a structure which is similar right across the geogrid.

6. The geogrid of Claim 4, wherein between the locations where the strands meet the bar, the bars are alternatively weakened and not weakened, the weakened zones in the bars on either side of the first-mentioned bars being staggered so that a weakened zone in one bar is aligned with a non-weakened zone in the bars on either side.

7. The geogrid of any of the preceding Claims, and made by uniaxially orienting a plastics sheet starting material which has been provided with holes.

8. A geogrid comprising at least three sets each of at least three spaced, parallel, substantially rectilinear tensile members which extend through the geogrid and each of which comprises a strand, a junction, a strand, a junction, and so on, each junction

interconnecting respective strands of the tensile member and the strands of the tensile member being substantially aligned with each other, the tensile members of each set making an angle with the tensile members of the other sets, and the junctions of one set also functioning as the junctions of at least one of the other sets, mesh openings being defined by the tensile members.

9. The geogrid of Claim 8, wherein each junction functions as a junction for a tensile member of each of the sets, whereby a tensile member of each of the sets intersects at the junction.

10. The geogrid of Claim 8 or 9, wherein there are three sets of tensile members.

11. The geogrid of Claim 10, and comprising strands and junctions at substantially each of which six of the strands meet, substantially each strand having each end connected to such a junction, whereby groups of three strands form triangular meshes with a junction at each corner.

12. The geogrid of any of Claims 8 to 11, wherein one set of tensile members is substantially in the transverse direction.

13. The geogrid of any of Claims 8 to 12, and made by biaxially orienting a plastics sheet starting material which has been provided with holes.

14. The geogrid of Claim 13, wherein at substantially each junction, the crotch between adjacent strands is oriented in the direction running around the crotch, whereby there is continuous orientation from the edge of one strand, around the crotch and to the edge of the adjacent strand.

15. The geogrid of Claim 13 or 14, wherein the centre of substantially each junction is oriented but substantially less oriented than the centre points of the strands.

16. The geogrid of Claim 15, wherein the centre of substantially each junction is biaxially oriented.

17. The geogrid of Claim 15 or 16, wherein the centre of substantially each junction has reduced in thickness by less than about 20%.

18. The geogrid of any of Claims 8 to 17, wherein said angle is substantially 60°.

19. A biaxially oriented plastics material geogrid, comprising:

angled oriented strands extending at an acute angle to a first direction;

further oriented strands extending in a second direction at right angles to the first direction; and

junctions each interconnecting four of the angled oriented strands and two of the further oriented strands;

as considered in the second direction, alternate angled strands being angled to the first direction by substantially equal and opposite angles.

20. The geogrid of Claim 19, wherein there are no oriented strands which extend substantially in the first direction.

21. The geogrid of Claim 19 or 20, wherein the junctions comprise two thicker zones each connecting two angled strands and a further strand, and a thinner zone interconnecting the two thicker zones.

22. The geogrid of any of Claims 19 to 21, wherein the orientation of the edge of substantially each strand runs around the edge of the respective junction and into the edge of the next strand.

23. The geogrid of any of Claims 19 to 22, wherein the angle between the axis of each angled strand and the first direction is between about 10° and about 20°.

24. The geogrid of any of Claims 19 to 22, wherein the angle between the axis of each angled strand and the first direction is about 30°.

25. The geogrid of any of Claims 19 to 24, and made by biaxially orienting a plastics sheet starting material which has been provided with holes.

26. The geogrid of any of Claims 19 to 25, wherein the first direction is the machine direction.

27. A method of making a uniaxially oriented plastics material geogrid, comprising:

providing a plastics sheet starting material which has holes in an array of hexagons of substantially identical shape and size so that substantially each hole is at a corner of each of three hexagons; and

applying a stretch to stretch out zones between adjacent holes on sides of the hexagons and form oriented strands from such holes, thereby forming a structure having bars at right angles to the direction of stretch, interconnected by the oriented strands.

28. The method of Claim 27, wherein each hexagon is substantially symmetrical about an axis which extends in the direction of stretch.

29. The method of Claim 27 or 28, wherein the stretch is applied in a direction substantially parallel to two sides of the hexagons, to stretch out zones between adjacent holes on the remaining four sides of the hexagons.

30. The method of any of Claims 27 to 29, wherein the sides of the hexagons are all substantially equal, as measured between the centres of the respective holes.

31. A method of making a biaxially oriented plastics material geogrid, comprising:

providing a plastics sheet starting material which has holes in an array of hexagons of substantially identical shape and size so that substantially each hole is at a corner of each of three hexagons;

applying a stretch in a first direction to stretch out zones between adjacent holes on sides of the hexagons and form oriented strands from such zones; and

applying a stretch in a second direction substantially at right angles to said first direction to stretch out zones between adjacent holes on the sides of the hexagons and form oriented strands from the latter zones, whereby centre portions of the hexagons form junctions interconnecting the oriented strands.

32. The method of Claim 31, wherein the stretch in the first direction is applied in a direction substantially parallel to two sides of the hexagons, to stretch out zones between adjacent holes on the remaining four sides of the hexagons, and the stretch in the second direction stretches out zones between adjacent holes on the sides parallel to the first direction.

33. The method of Claim 31 or 32, wherein each hexagon is substantially symmetrical about an axis which extends in the first direction.

34. The method of any of Claims 31 to 33, wherein each hexagon is oriented so that two opposite holes delineating the hexagon are substantially aligned in the first direction.

35. The method of any of Claims 31 to 34, wherein the sides of the hexagons are all substantially equal, as measured between the centres of the respective holes.

36. The method of any of Claims 31 to 35, wherein the dimension of each hexagon in the first direction, as measured from the centre of one hole to the centre of the opposite hole of the hexagon in the machine direction, is less than the corresponding dimension between respective pairs of the other holes.

37. The method of Claim 36, wherein the ratio of the first-mentioned dimension to the other dimensions is greater than 0.75:1.

38. The method of Claim 36 or 37, wherein the ratio of the first-mentioned dimension to the other dimensions is less than about 0.95:1.

39. The method of any of Claims 36 to 38, wherein the ratio of the first-mentioned dimension to the other dimensions is greater than about 1:1.1.

40. The method of any of Claims 36 to 39, wherein the ratio of the first-mentioned dimension to the other dimensions is less than about 1:1.3.

TS

41. A method of making an oriented plastics material geogrid, comprising:

providing a plastics sheet starting material which has through holes and also blind holes which do not penetrate right through the sheet and have been formed by forming depressions when the plastics material is at a temperature which is below the lower limit of its melting range; and

stretching the starting material so that the through holes and the blind holes form meshes separated by oriented strands.

42. The method of Claim 41, wherein the starting material is uniaxially oriented.

43. The method of Claim 41, wherein the starting material is biaxially oriented.

44. A method of making an oriented plastics material geogrid, comprising:

providing a plastics sheet starting material which has substantially through holes on a rectangular grid whose axes extend in a first direction and in a second direction substantially at right angles to the first direction, thereby providing first rows of holes extending in the first direction and second rows of holes extending in the second direction, and which starting material has weakened zones between alternate pairs of adjacent holes in each first row, the weakened zones being staggered as between adjacent first rows so that a weakened zone in one first row is adjacent a non-weakened zone in the adjacent first row on either side;

applying a stretch in the first direction to stretch out zones between adjacent holes in each second rows to form oriented strands from such zones; and

applying a stretch in the second direction to stretch out the weakened zones to form oriented strands from the weakened zones without stretching out non-weakened zones between adjacent holes of in the first rows to the same extent as the weakened zones are stretched;

whereby the non-weakened zones form junctions each of which interconnects six of the oriented strands.

45. The method of any of Claims 31 to 40 and 44, wherein the orientation of the edge of substantially each strand runs around the edge of the respective junction and into the edge of the next strand.

R.

46. The method of any of Claims 31 to 40, 44 and 45, wherein the centre of the junction thins down but by less than about 20% of the starting material thickness.

47. The method of any of Claims 31 to 40 and 44 to 46, wherein the first direction is the machine direction.

48. The method of Claim 47, wherein the stretches are carried out sequentially, the first stretch being the stretch in the first direction.

49. The method of any of Claims 31 to 40 and 44 to 48, wherein there are strands which extend in the second direction and which are stretched out to a greater stretch ratio than the other strands.

50. A geogrid made by the method of any of Claims 27 to 49.

51. A uniaxial geogrid substantially as herein described with reference to Figures 2 and 3 or Figure 10 of the accompanying drawings or in the foregoing Examples 1 and 2.

52. A biaxial geogrid substantially as herein described with reference to Figures 4 and 5 or Figure 11 of the accompanying drawings or in the foregoing Examples 1 and 2.

53. A method of making a uniaxial geogrid, substantially as herein described with reference to Figures 1 to 3 or Figures 9 and 10 of the accompanying drawings or in the foregoing Examples 1 and 2.

54. A method of making a biaxial geogrid, substantially as herein described with reference to Figures 1 to 5 or Figures 9 to 11 of the accompanying drawings or in the foregoing Examples 1 and 2.

55. A method of strengthening a particulate material, comprising embedding in the particulate material the geogrid of any of Claims 1 to 26, 50, 51 and 52.

56. A particulate material strengthened by the method of Claim 55.

57. A geoengineering construction comprising a mass of particulate material strengthened by embedding therein a geogrid as claimed in any of Claims 1 to 26, 50, 51 and 52.

ABSTRACT:

Geogrid

To make an oriented plastics material geogrid 10 in which oriented strands 6, 9 form triangular meshes with a junction 11 at each corner and six of the strands 6, 9 meet at each junction 11, a plastics material sheet starting material 1 has holes 2 in an array of hexagons 3, opposite holes 2 of each hexagon being aligned in the machine direction, and the starting material 1 is stretched first in the machine direction and secondly in the transverse direction. In the eventual geogrid 10, the centre portions of the hexagons in the starting material 1 form the junctions 11. The centres of the junctions 11 are slightly biaxially oriented, but at the edges of the junctions 11, the orientation of the edge of substantially each strand 6 or 9 runs around the edge of the respective junction 11 and into the edge of the next strand 6 or 9. If desired, the procedure can be terminated after the first stretch, to produce a uniaxially-oriented geogrid.

(Figures 1 and 4)

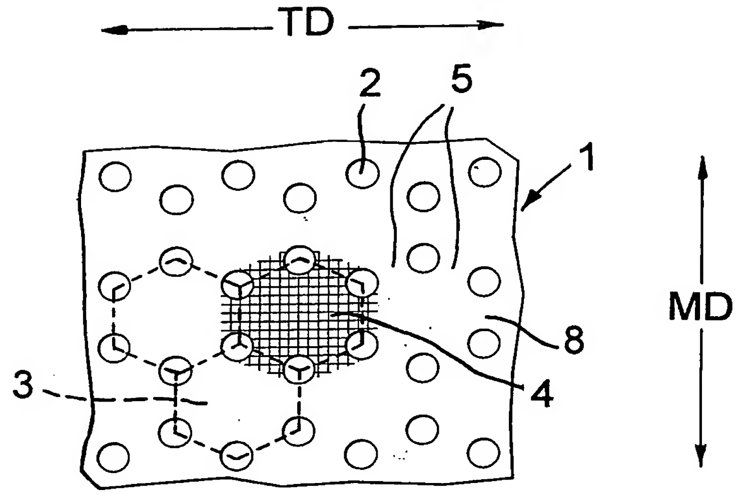

Fig.1

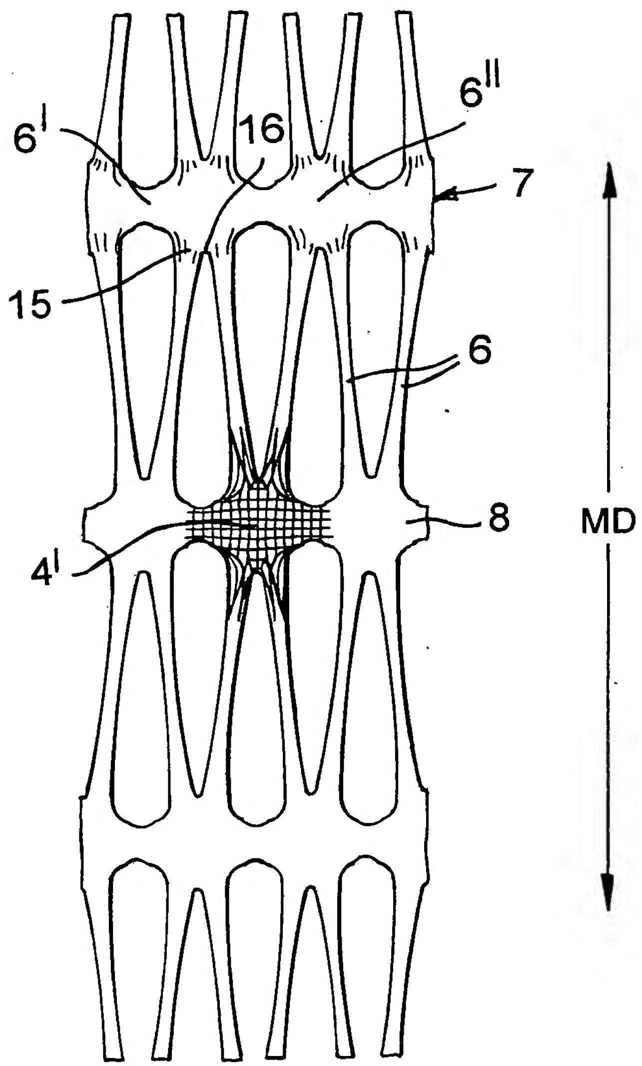

Fig.2

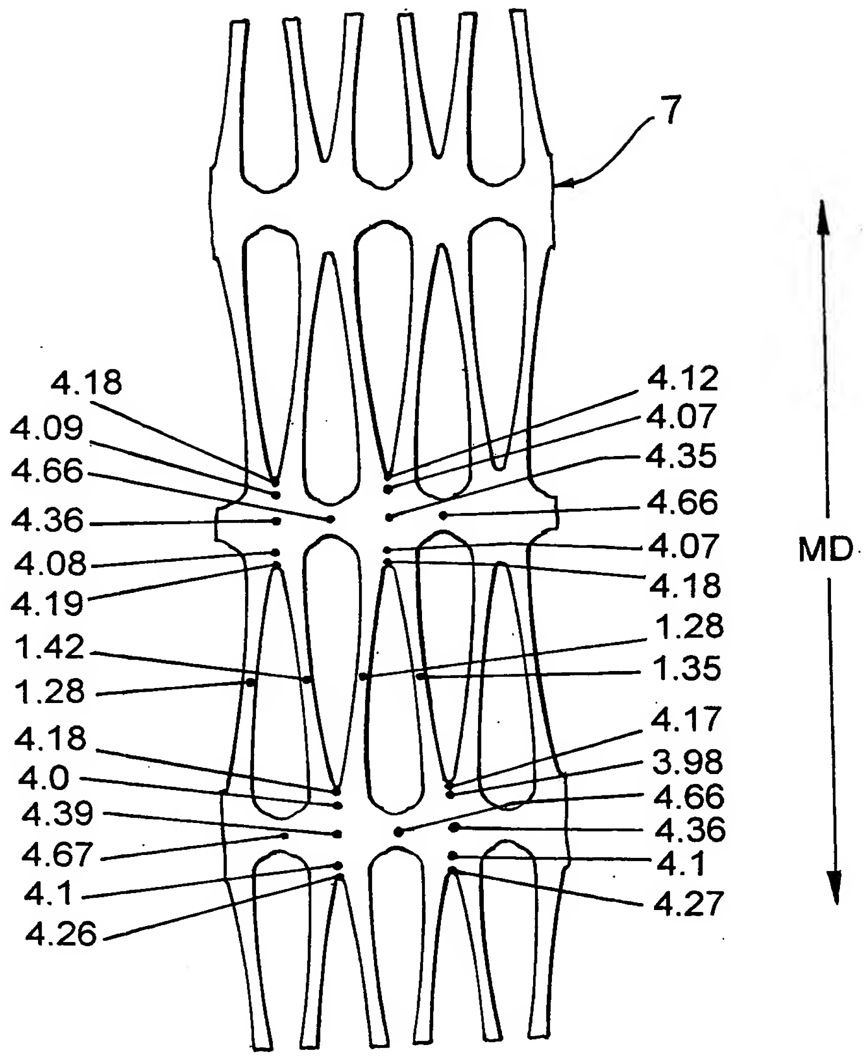
7
4.18
4.09
4.66
4.36
4.08
4.19
1.42
1.28
4.18
4.0
4.39
4.67
4.1
4.26
4.12
4.07
4.35
4.66
4.07
4.18
1.28
1.35
4.17
3.98
4.66
4.36
4.1
4.27
MD

Fig.3

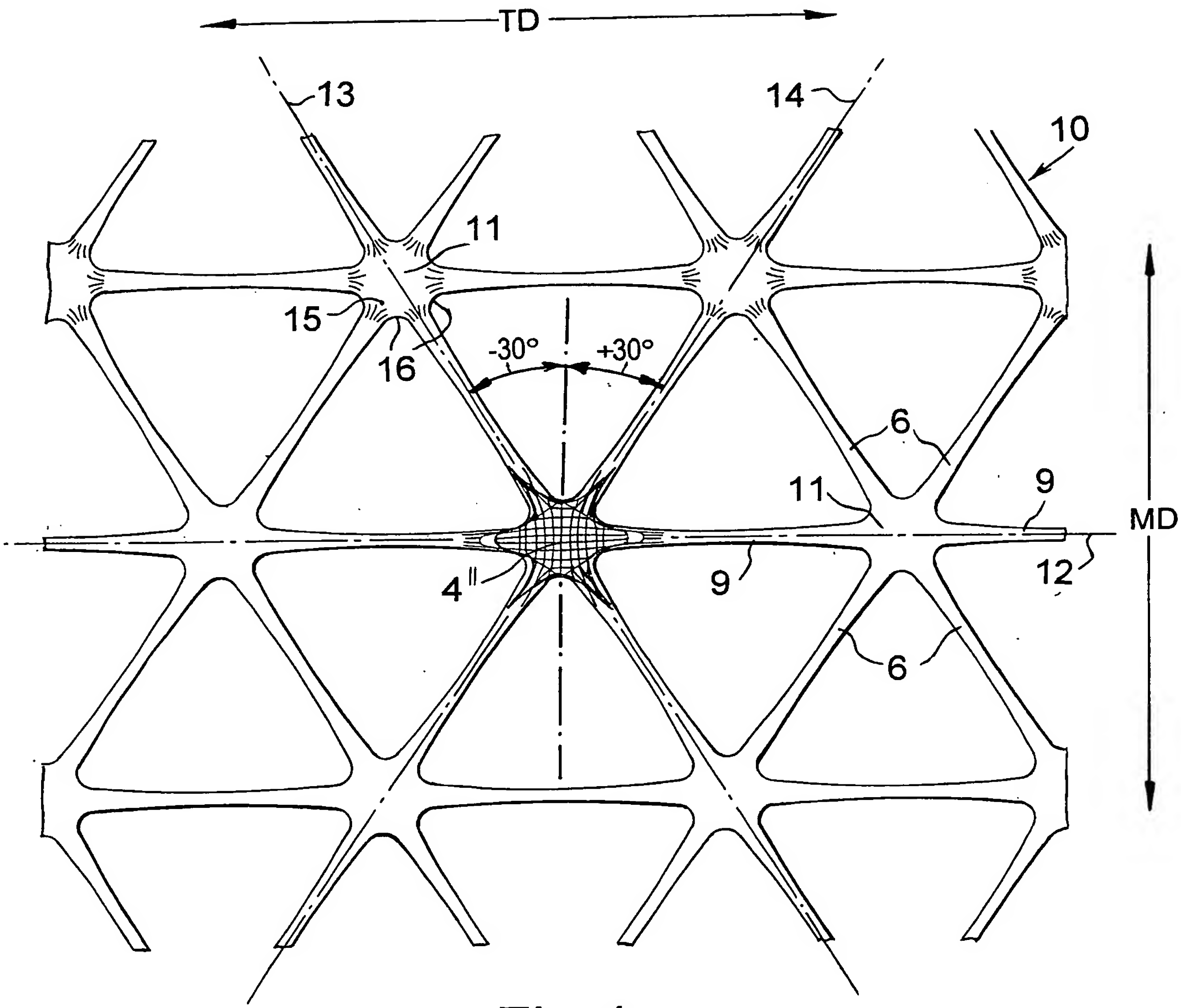

Fig.4

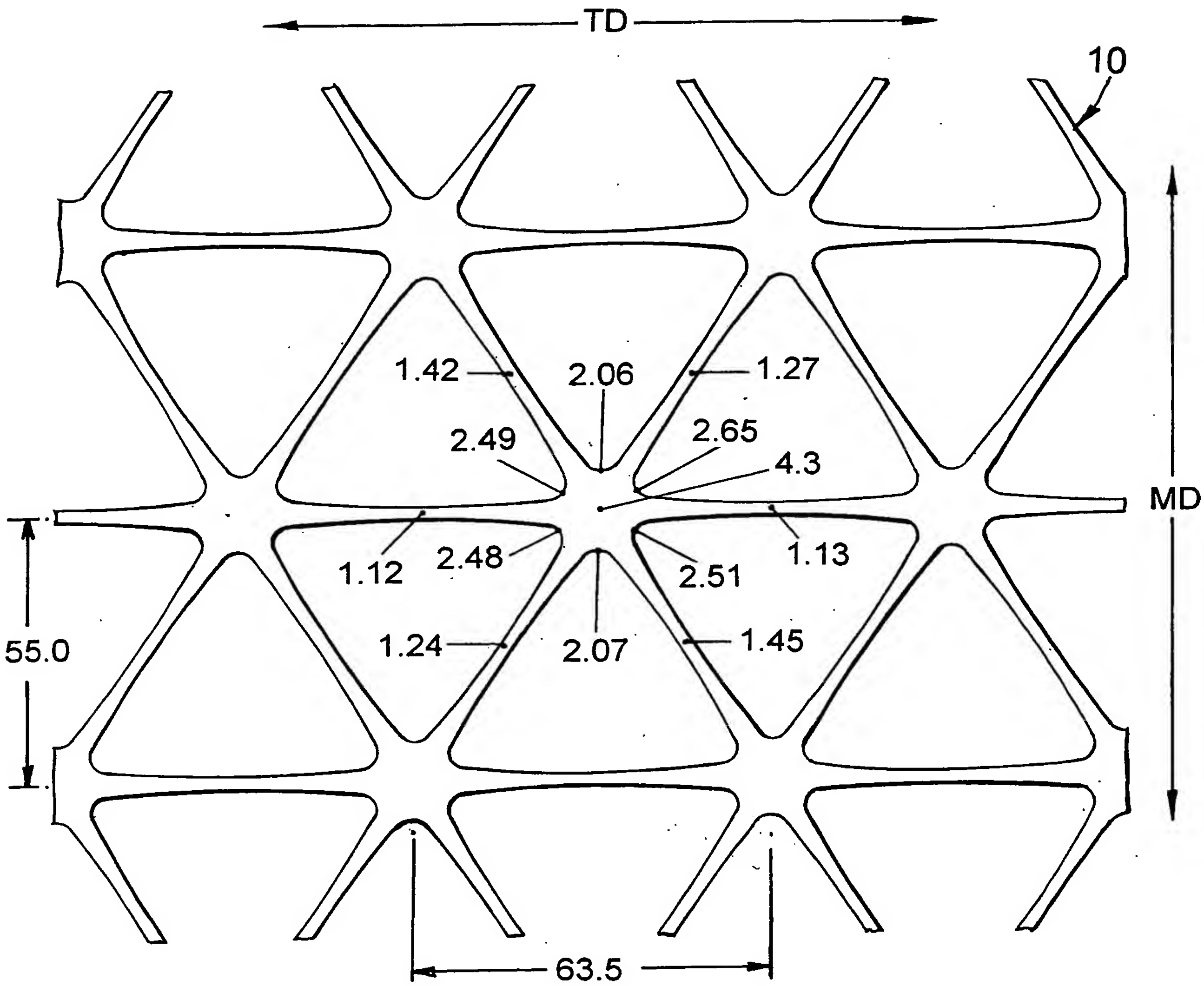
TD
10
MD
1.42
2.06
1.27
2.49
2.65
4.3
1.12
2.48
2.51
1.13
1.24
2.07
1.45
55.0
63.5

Fig.5

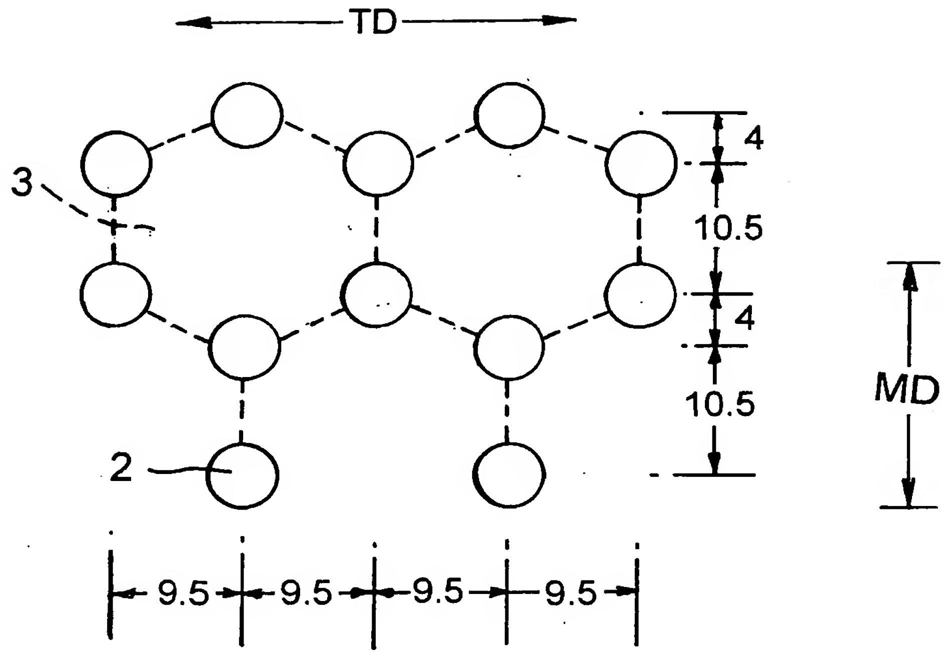

Fig.6

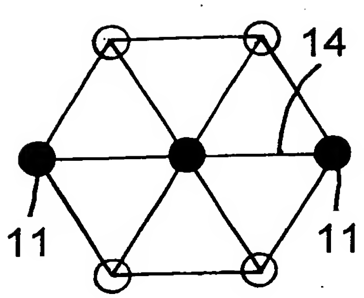

Fig.7a

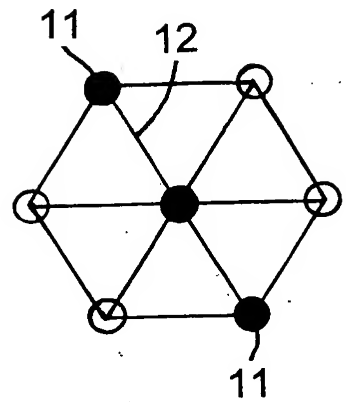

Fig.7b

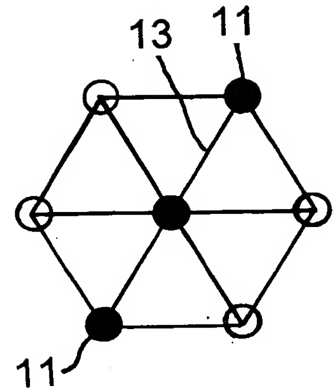

Fig.7c

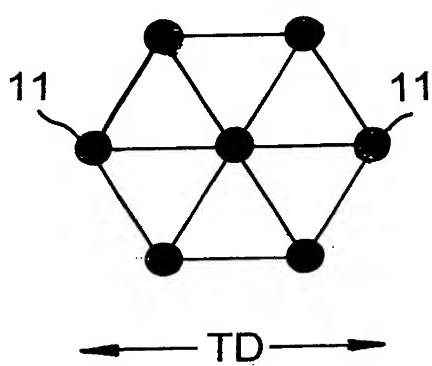

Fig.8a

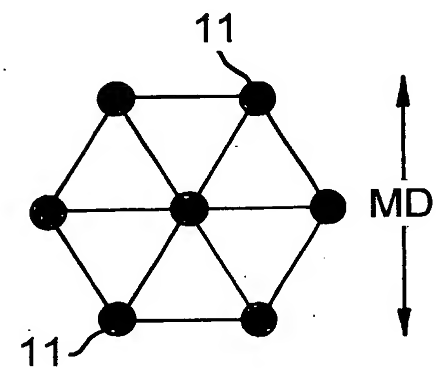

Fig.8b

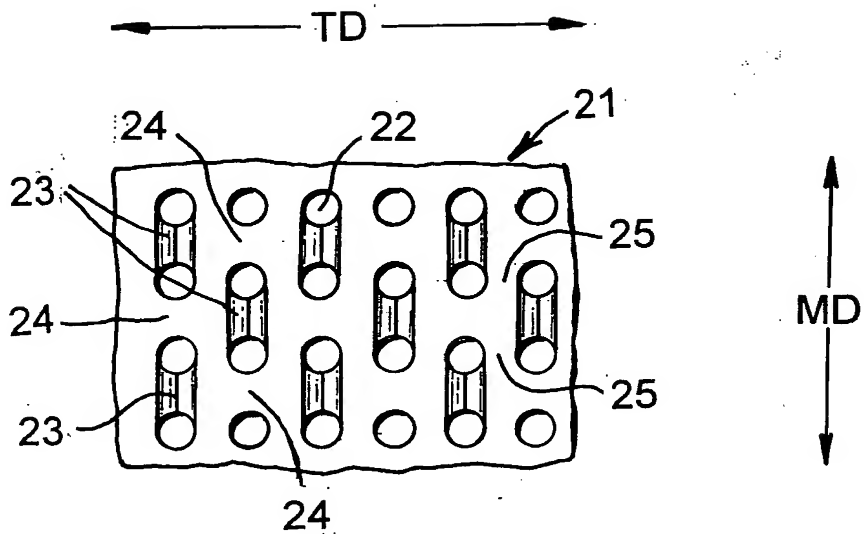

Fig.9

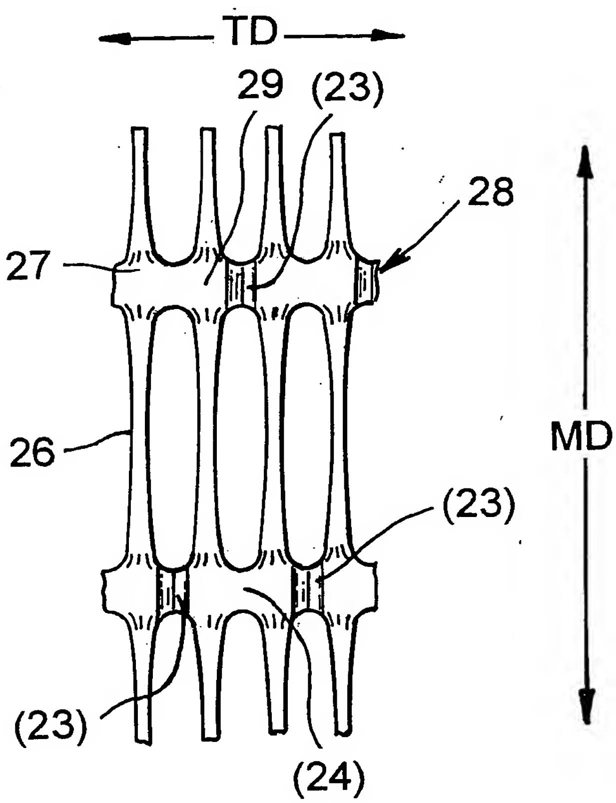

Fig.10

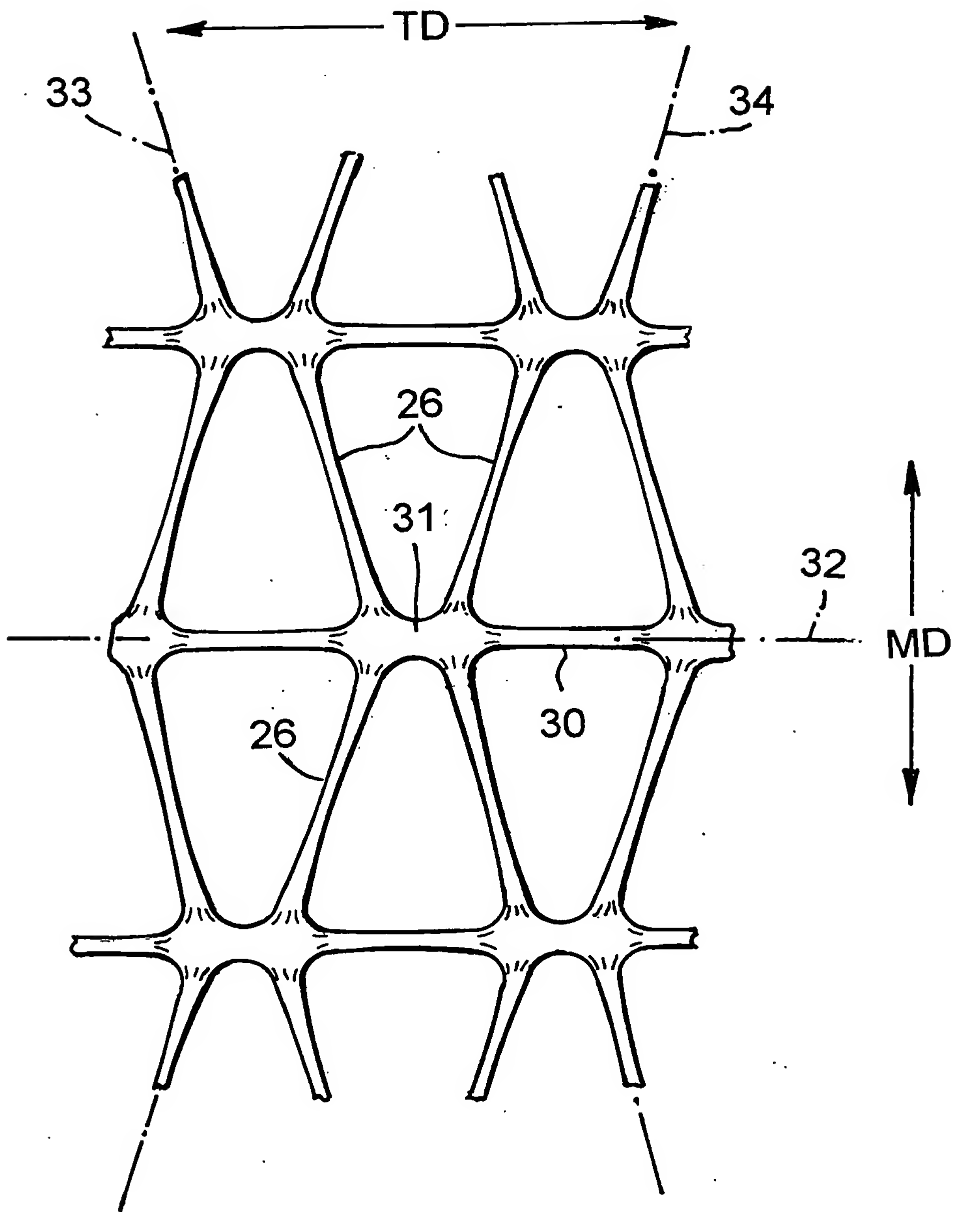

Fig.11

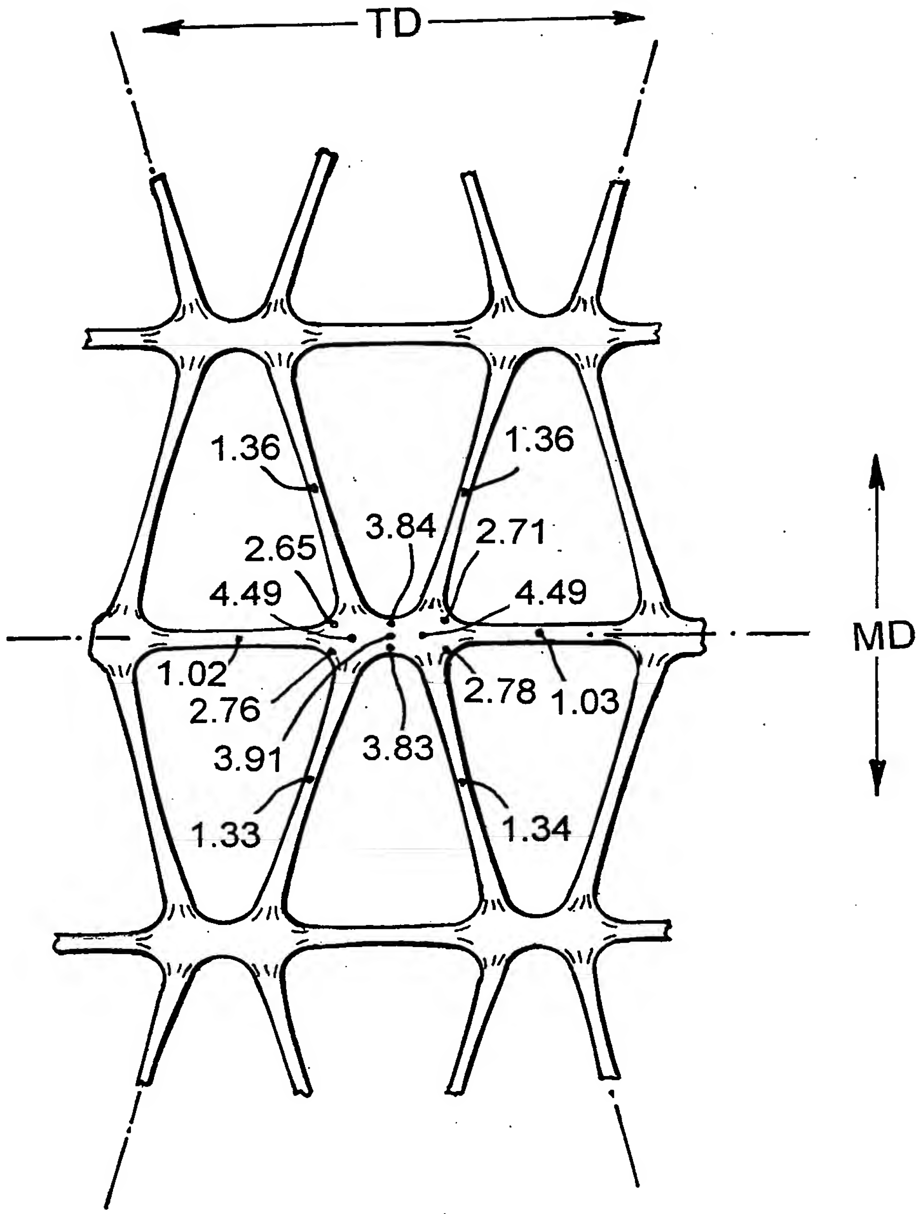

Fig.12